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Some Factors Affecting the Pectin Grade of Apple Pomace[a]

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Pomace samples were prepared, dried in a laboratory drier under varying conditions of temperature and time, and evaluated for pectin grade. Apples were kept in cold storage, and the changes in grade of pomace observed. Pomace from rotten apples was compared with that from sound apples. The effect of allowing pomace to stand before drying was studied. Pomace dried by various commercial methods was compared with that dried in the laboratory drier.

The commercial value of apple pomace depends largely on the amount and quality of the pectin that may be extracted. It is well known that the grade or quality of pomaces varies widely with the source of raw material and the method of treatment. Several of the factors affecting pomace grade have previously been studied. For example, Burroughs, Kieser, Pollard and Steedman *(2)* have compared the jellying power of pomace from immature, normal and overripe apples. Charley, Burroughs, Kieser and Steedman *(4)* have reported on the effect of allowing pomace to stand before drying. Mottern and Karr *(5)* have discussed the grades of various types of commercial pomace. The work described in this paper was undertaken in order to extend the information available from the foregoing sources, as well as to find other variables that might be related to pomace grade.

EQUIPMENT AND MATERIALS

The first requirement for these studies was to develop a standard method for drying pomace in the laboratory. The drier utilized for this purpose is portrayed in Figure 1, which shows a vertical cross section. The frame is constructed of plywood panels, the front panel being removable to give access to the four drying trays, which slide in and out on ⅜" by ½" wooden cleats. The trays, 1, 2, 3 and 4 are 8½" by 9", inside dimensions, and are made from ⅜" by 1" wooden frames, with bottoms of 18-mesh bronze screen. The heat is provided by two 600-watt nichrome heating elements, denoted by the numeral 5, placed below the trays and controlled by a 3-position switch, 6. A sheet-metal baffle plate, 7, prevents fine material from falling on the heating elements.

Circulation is provided by a 40-watt rotary blower, 8, mounted in the top of the drier. The direction of circulation is shown in the figure. Adjustable vents, 9 and 10 are provided to control the circulation. Vent 9 is normally kept closed. When vent 10 is fully open, the hot air—drawn upward through the trays—is largely exhausted; but recirculation may be increased by partially closing this vent. Recirculation makes the control of temperature more difficult and increases the danger of overheating. Therefore, in the current studies, vent 10 was left fully open at all times. A thermometer, 11, is inserted through a hole in the side panel between the second and third trays.

The normal load of pomace was about 700 g. per run, or 175 g. per tray, which is approximately 350 g. per sq. foot of tray area. The blower was started, and the heater turned to the high position until the desired maximum temperature was approached. The switch was then turned to medium or low, and the temperature maintained by alternating between 2 adjacent positions. With a little practice, a fairly constant temperature could be maintained in this way. In later experiments, a variable transformer was inserted between the heater and the source of current, permitting closer temperature control with less attention.

During the drying, the positions of the trays were shifted or rotated every 15 minutes by removing the bottom tray, shifting the other trays down one position, and replacing the bottom tray in the top position. The moisture contents of the dried pomaces ranged from 1 to 5%.

EXPERIMENTAL PROCEDURES AND RESULTS

Preparation of pomace. The apples were washed and carefully trimmed to remove all damaged tissue and then passed through a hammer mill. Fixed blades with a blunt serrated edge, and a screen with ½" holes were used. The pulp was immediately pressed on a hydraulic press with a 17" square platen. The press cake was broken up by hand and re-pressed on a laboratory-type hydraulic press. The resulting material (containing from 60 to 72% moisture) was again broken up, spread out on the drying trays, and dried. The dried pomace was weighed and stored in air-tight jars.

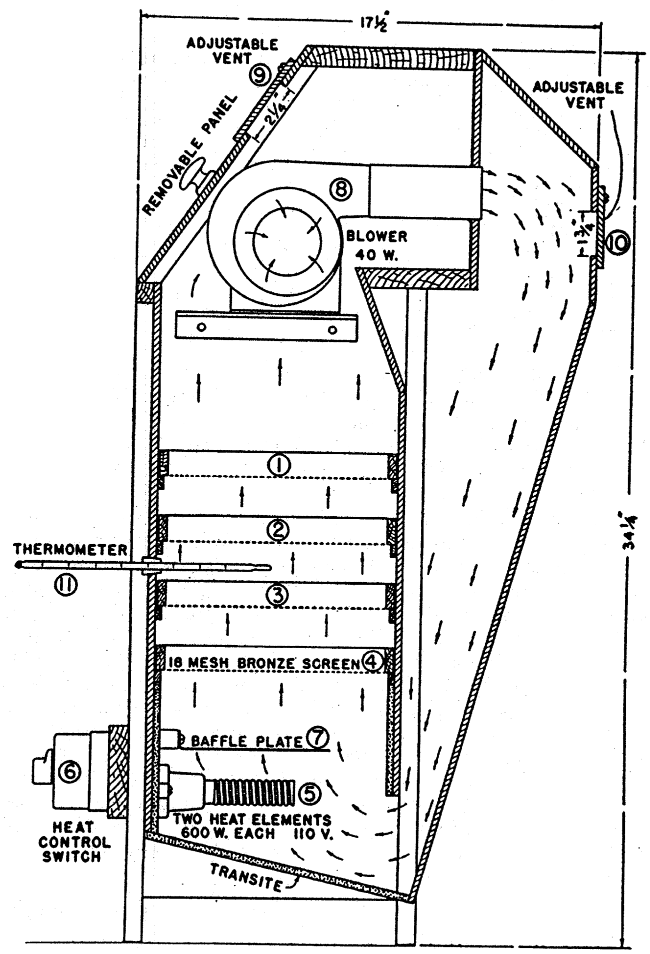

Figure 1. Cross section of laboratory pomace drier, showing circulation of air through drying trays (1, 2, 3, and 4).

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Evaluation of pomace. The grade of a pomace may be defined as the number of grams of sugar that can be converted into a jelly of standard strength by the pectin extracted from one gram of the dry pomace. For testing the jellies, use was made of the Delaware Jelly Tester, developed by Baker *(1)*, which measures the hydrostatic pressure, in centimeters of water, required to break the jellies by forcing a plunger of standard dimensions through the surface. The instrument was calibrated *(5)* by measuring the values for jellies made up with varying quantities of a standard pectin and plotting the ratio of true grade to assumed grade against these values to give a calibration curve.

The method used for the extraction of the pomace and the preparation of the test jellies was based on the method of Mottern and Karr *(5)*, with several modifications, and with several features proposed by W. A. Rooker *(7)*. The dried pomace was ground in a Wiley mill to pass a 4-mm. screen, and the moisture content was determined by drying in a vacuum oven at 70° C. to constant weight. One hundred g. of ground pomace were weighed into a tared 2-liter beaker. Four g. of commercial sodium tetraphosphate, $Na_6P_4O_{13}$,[c] were added, followed by 1500 ml. of water. The pH of the mixture was brought to 3.2 by the addition of hydrochloric acid (1:1). It was then heated to the boiling point and held at 90° to 100° C. for 30 minutes. After cooling to 50° C., the beaker was weighed and net contents recorded. The suspension was then drained through cheesecloth. The viscosity of the drained liquid was determined by means of an Ostwald viscosimeter, and the percentage of soluble solids by reading from the sugar scale of an Abbe refractometer.

The amount of extract to be taken for the preparation of the test jellies depends upon the grade of the pomace. This may be estimated roughly from the viscosity of the extract. Table 1 indicates the amount of sample required for extracts of various relative viscosities. In most cases these values gave jellies falling within suitable limits for testing. With pomaces of very low grade, it was necessary to concentrate the extract by vacuum evaporation.

TABLE 1

Relative viscosity versus weight of extract and assumed grade

Relative viscosity of extract	Weight of extract required grams	Assumed grade of extract
Under 15	340	1.53
15-25	320	1.63
25-35	300	1.74
35-45	280	1.86
45-55	260	2.00
55-65	240	2.17
65-75	220	2.36
Over 75	200	2.60

The extract was weighed, in duplicate, into tared 800-ml. beakers. If the weight of sample used was less than 340 g., it was made up to that amount by the addition of water. The liquid was heated to boiling on a hot plate, and 520 g. of sucrose, less the weight of solids in the extract (calculated from the refractometer reading), were added and dissolved as rapidly as possible by stirring. The beaker was returned to the hot plate, and the boiling continued until the net weight of the solution was reduced to 800 g. The solution was then allowed to cool, with a thermometer suspended so that the bulb was near the center of the liquid. When the solution had cooled to 97° C., it was skimmed, and at 96° C. poured rapidly into six 100-ml. beakers, each containing 2.4 ml. of tartaric acid solution (287 grams per liter). The acid was distributed by stirring briskly for 3 to 5 seconds. The beakers were covered when cool enough to avoid the condensation of moisture on the under side of the watch glass covers. The jellies stood overnight before testing.

The jellies were tested without being removed from the beaker. Readings of pressure to the nearest centimeter were taken at the instant when the plunger broke through the surface of the jelly. The 6 readings for each batch of jelly were averaged (after eliminating any reading that varied more than 20% from the average), and the ratio of "true grade" to "assumed grade" was read from the calibration curve. The grade of the pomace was calculated from the following equation:

$$G = \frac{AG \times R \times W}{S}$$

where G = the grade of the pomace; AG = the assumed grade given in Table 1 (obtained by dividing the weight of sugar by the weight of extract); R = the ratio of true grade to assumed grade as determined by the jelly test, W = the total weight of the extraction mixture; and S = the weight of the pomace sample taken, on the moisture-free basis.

Effect of drying temperature. Optimum drying temperature was determined by drying samples of the same pomace at maximum temperatures of 110°, 100°, 90°, 80°, 70° and 60° C. (230°, 212°, 194°, 176°, 158° and 140° F.). The grades of the dried pomaces increased with decreasing drying temperatures from 110° to 90° C. (230° to 194° F.), at which point pomace of maximum grade was obtained. Drying was complete in one hour at this temperature. At lower temperatures the drying period was longer, and since no improvement in grade was obtained by further reduction of the temperature, 90° C. (194° F.) was chosen as the maximum drying temperature in all succeeding experiments.

Due to the position of the thermometer between the two middle trays of the drier, the temperatures shown here do not represent the temperature of either the incoming or outgoing air, but an intermediate value. No measurement was made of the temperature gradient between the air passing through the bottom and top trays, but the short distance between the two, and the relatively high air velocity, would indicate that the gradient would not be great.

Although these results seem to indicate that drying in the laboratory drier at 90° C. (194° F.) causes little or no degradation of the pectin, it is, of course, impossible to state categorically that such is the case. In an effort to check this point, an attempt was made to find methods that might offer less chance of damage to the pectin. The 2 methods chosen were: drying in a vacuum oven at various temperatures below 90° C. (194° F.), and drying under an infrared heat lamp. Combinations of these were also tried. These methods proved to be very slow in comparison with the laboratory drier, and in no cases were pomaces of higher grade obtained.

Effect of length of storage. Carré and Horne *(3)* found that the total pectic compounds in apples (determined by precipitation as calcium pectate) remained practically constant, during cold storage, for about 6 months, but that the pectic constituents of the middle lamella began to decrease slowly after 2 months and more rapidly after 4 months.

Burroughs et al. *(2)* found that with Dabinett, an English variety, pomace from immature apples was slightly higher, and from overripe apples slightly lower in jellying power than that from fruit of normal maturity.

The examination in this laboratory of pomace samples taken regularly from an apple juice plant during a single season (October through February) gave the results shown in Figure 2, where pomace grade is plotted against date of pressing. All samples represent blends of varieties, and the composition of the blends naturally varied considerably from time to time. However, no correlation of predominant varieties with grade could be found. Investigation of the source of the apples showed that during the harvesting season freshly picked apples were used. During the last half of November and the first half of December, most of the fruit was drawn from common storage. From mid-December, cold storage apples were used in gradually increasing proportion until, in late January and February, they accounted for the entire amount. The shape of the curve suggests that the use of common storage apples was reflected in lowered grade of pomace, but that the introduction of cold-storage apples brought the grade back up to its original average.

Laboratory tests on the effect of cold storage on pomace grade were made during 2 different seasons. In the first experiment, batches of utility grade McIntosh, Golden Delicious, Jonathan, Stayman Winesap and Rome Beauty apples were

[c] Kindly supplied by Rumford Chemical Works, Rumford, Rhode Island.

TABLE 2

Effect of storage period of apples on pomace grade (1946-47)

Variety	Grade at 1st test	Days from 1st test	Grade	Days from 1st test	Grade	Days from 1st test	Grade
McIntosh	32.4	47	35.7	79	31.6	112	28.1
Golden Delicious	39.6	48	29.6	78	22.8	......	......
Jonathan	31.9	49	32.2	80	35.2	115	29.6
Stayman Winesap	18.8	49	32.5	83	22.1	116	26.0
Rome Beauty	36.4	35	36.9	70	35.8	101	32.5
Average	31.8		37.4		29.5		30.1

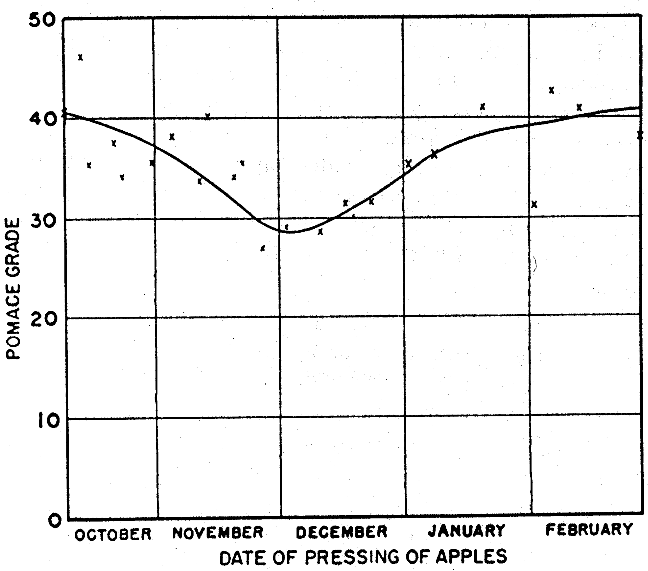

Figure 2. Grades of pomace samples obtained from an apple juice plant during a typical season (1946-47). Values for November and early December represent largely apples taken from common storage. From mid-December, cold storage apples were used in gradually increasing proportion until, in late January and February, they accounted for the entire amount.

taken from cold storage and each batch thoroughly mixed. A half bushel of each variety was ground and pressed, and the pomace dried and graded as described above. The remainder of the apples were kept in cold storage, and samples were removed and graded at intervals. The results are given in Table 2. Of the 5 varieties, Golden Delicious and Stayman were the only ones that showed a marked decrease during any part of the period. The other varieties showed some decrease in the last column, which may or may not be significant.

In the second experiment, juice grade apples of 4 varieties (Stayman Winesap, McIntosh, Red Delicious and Rome Beauty), picked in October, were placed in storage at 35° F. in a room containing an activated-carbon air purifier. The Stayman Winesap and Red Delicious were largely of normal maturity and color, but varied in size and shape. The McIntosh and Rome Beauty were small and rather immature. Samples of pomace from each variety were prepared and graded at 1-month intervals, beginning after one month's storage and extending to 6 months. During this period all varieties underwent considerable deterioration. The Stayman Winesap suffered mostly from splitting and the Red Delicious from dry rot. The other varieties developed ordinary soft rot during the latter part of the period. All varieties eventually showed some shrivelling. With the exception of the Red Delicious, all varieties were rather badly rotted by the end of the 6-months' period. In preparing the pomace, of course, only sound tissue was used. Table 3 shows the variation of pomace grade with time of storage of the 4 varieties. The values seem to show no regular trend, and considering the limitations of the grading method and the possibilities of sampling error, the variations were not large until the fifth or sixth month, at which stage all varieties except Red Delicious showed an appreciable drop. It is probably safe to conclude that for the varieties and conditions employed there is no marked change in the grade of pectin in the sound tissue from the first month of storage until the approach of deterioration.

Effect of rotten fruit. The next question to be studied was the effect of the presence of rotten tissue in the pomace. At the conclusion of the storage period (6 months) the remainder of the McIntosh apples from the preceding experiment were approximately half rotten. They were ground without sorting or trimming, and the pomace was prepared in the usual way. This pomace had a grade of 13.6, as compared with 24.5 for sorted and trimmed apples from the same batch. This seems to confirm the natural assumption that rotting results in decomposition of the pectin.

Effect of delay in drying. It is not generally recognized in this country that pomace must be dried promptly after pressing if the grade is to be maintained. Charley et al. in England *(4)* found that pomace which was allowed to stand before drying lost from 21 to 39% of its jellying power in one day, and from 40 to 49% in 2 days. In order to determine the rate of deterioration, pomace was prepared from Stayman Winesap and from Red Delicious apples (3 months' storage) in the manner previously described. One portion from each variety was dried immediately, and other portions were allowed to stand at room temperature for 1, 2, 3 and 6 days, respectively, before drying. Within one day a faint moldy odor was detectable. In 2 days the moldy odor was quite noticeable. In 3 days the odor was quite strong and mold growth was distinctly visible. After 6 days, both samples were very moldy. The results of the grade determinations of these samples are shown in Table 4. The losses in grade amounted to about 40% after one day, and about 50% after 2 days. The extracts prepared from samples that had stood for 3 days or longer gave jellies which were too weak to test, indicating a loss of more than 60%.

Peel and core pomace. Since pomace is prepared commercially both from whole apples and from peels and cores, it is of interest to know how the pomace from peels and cores compares in grade with that from the remainder of the apple. Samples of Stayman Winesap, York Imperial, and Rome Beauty were peeled and cored. The peels and cores were ground and pressed, and the pomace was dried and graded. The remaining portions of the apples were similarly treated. Two of the varieties were tested again in the same manner after about 3½ months' cold storage. The results, shown in Table 5, show that the pomace from peels and cores was from 25 to 70% higher in grade than that from the rest of the apple tissue.

TABLE 3

Effect of storage period of apples on pomace grade

Date of preparation of pomace	Months in storage	Grade of Pomace			
		Stayman	McIntosh	Red Delicious	Rome Beauty
November	1	27.8	25.2	27.6	29.2
December	2	26.8	25.0	28.8	27.4
January	3	26.3	......	30.2	......
February	4	29.6	26.2	30.0	26.1
March	5	24.9	27.6	27.2	28.8
April	6	22.4	24.5	27.5	24.8

TABLE 4

Effect of time of standing before drying on pomace grade

Variety	Grade after standing for				
	0	1 day	2 days	3 days	6 days
Red Delicious	30.2	18.1	14.6	Too low to test[d]	
Stayman Winesap	26.3	15.3	13.1	Too low to test[d]	

[d] Below 10.0.

TABLE 5

Comparison of grade of pomace from peels and cores with that from remainder of apple

Variety	Fraction	Grade before storage	Grade after 3½ months' storage
Stayman	Peels and cores	28.9	27.7
	Remainder	18.7	16.2
Rome Beauty	Peels and cores	38.8	31.8
	Remainder	25.0	21.2
York	Peels and cores	21.8	......
	Remainder	17.3	......

Comparison of Commercial Drying Methods

The purpose of this part of the study was to compare the effect of various commercial drying methods with that of the laboratory drier and, if possible, with each other, with regard to pectin grade. The laboratory drier was taken to 3 successive apple processing plants and set up near the pomace drying equipment. A sample of wet pomace was taken from the line just before entering the drier, and dried on the laboratory apparatus. The length of time required for pomace to pass through the commercial drier was estimated, and after that interval a sample of the material emerging from the dry end was collected. These 2 samples, which were obviously alike before drying, were paired together in the grade comparison. Six pairs were obtained from each plant.

The first plant visited was making canned sliced apples from York Imperial. The peels and cores, together with some cull apples, were ground and pressed. The pomace was reground and pressed again before drying. The drier was a Rotolouvre type, 24 feet long by 6 feet in diameter. Flue gas from a coke furnace was used as the drying agent. The gas entered the furnace at 550° F. and left it at 230° F. The estimated time required for the pomace to pass through the drier was 20 minutes. The average moisture content of the dried pomace was about 7%. Table 6 shows the grades of the six pairs of samples dried on this equipment and on the laboratory drier. The mean difference in grade was 5.5 points in favor of the laboratory drier, and the application of "Student's" formula for paired samples *(6)* shows that this difference is significant.

The second plant (which was under the same management as the first) was using the same kind of apples and making a similar product. The drier was of the same type, but was 20 feet long and 5 feet in diameter. Steam-heated air was used as the drying agent. The hot air entered the drier at 330° F. and left it at 160° F.

TABLE 6

Grades of pomace samples. Comparison of laboratory drier with commercial direct-fired rotolouvre drier

Pair number	Grade of pomace dried in		Difference
	Laboratory drier	Commercial drier	
1	38.5	34.3	4.2
2	38.3	36.6	1.7
3	34.0	28.6	5.4
4	35.6	29.5	6.1
5	37.9	25.9	12.0
6	36.2	32.3	3.9
Mean	36.7	31.2	5.5[e]

[e] Sigificant at 5% level.

The estimated time of passage through the drier was 45 minutes. The average moisture content was below 3%. Samples were taken in the same way as before. Table 7 shows a mean difference in grade of 2.5% in favor of the laboratory drier. Comparison with Table 6 shows that the mean grades obtained with the laboratory drier were essentially the same in both cases, as would be expected from the similarity of the raw material. The difference in grade of the commercially dried samples must therefore be due to the difference in drying methods. The mean difference in Table 7, although less than half as great as that in Table 6, is still statistically significant. It may be concluded that both of these commercial driers gave pomace of somewhat less than the maximum possible grade, and that the direct fired drier gave somewhat lower grades and more variation. Probably these differences reflect only the differences in operating temperatures between the 2 driers, and have nothing to do with the use of flue gas or heated air *per se*.

TABLE 7

Grades of pomace samples. Comparison of laboratory drier with commercial steam-heated rotolouvre drier

Pair number	Grade of pomace dried in		Difference
	Laboratory drier	Commercial drier	
1	36.7	33.7	3.0
2	39.7	34.6	5.1
3	37.8	35.8	2.0
4	36.0	34.4	1.6
5	38.1	34.8	3.3
6	33.7	34.0	—0.3
Mean	37.0	34.5	2.5[f]

[f] Significant at 5% level.

The third plant was making apple sauce from a mixture of varieties, with Rhode Island Greening predominating. The peels and cores were ground and pressed only once. The drier was a rotary steam-tube type, using steam at a pressure of 40 pounds per sq. inch. The temperature within the drier was not recorded. The estimated time of passage through the drier was one hour. It was observed that some of the wet pomace stuck to the tubes and was scorched. This was probably due to the high moisture content of the single-pressed pomace. The average moisture content of the product was about 7%. The data, shown in Table 8, indicate a mean difference of 7.7 points in favor of the laboratory drier. Since the raw material and the process were obviously quite different from those in the other plants, no comparisons can fairly be made between the relative merits of the steam tube drier

TABLE 8

Grades of pomace samples. Comparison of laboratory drier with commercial rotary steam-tube drier

Pair number	Grade of pomace dried in		Difference
	Laboratory drier	Commercial drier	
1	28.7	24.5	4.2
2	29.7	18.2	11.5
3	24.0	18.5	5.5
4	23.8	19.6	4.2
5	26.2	15.8	10.4
6	24.4	13.9	10.5
Mean	26.1	18.4	7.7[g]

[g] Significant at 1% level.

and the Rotolouvre driers. It can only be stated that under the circumstances here described the differences in grade, in favor of the laboratory drier, were quite marked and highly significant. This pomace, as may easily be guessed, could be disposed of only as stock feed.

It should be observed here that in commercial pomace drying, accurate control of temperature and an even flow of material into the drier are essential for the maintenance of a good pomace grade. Carelessness in attention to these details sometimes results in obvious scorching, and probably even more frequently in damage which, although not visible, is reflected in lowered grade.

SUMMARY

Apple pomace may be dried in a laboratory drier at 90° C. (194° F.) with maximum retention of grade. Pomace from apples kept in cold storage shows, in most cases, no marked change in grade, when only sound tissue is used, until the approach of complete deterioration. The inclusion of rotten tissue lowers the grade. Pomace which is allowed to stand at room temperature before drying loses about 40% in grade after one day and about 50% after 2 days; after 3 days it is too low to test, indicating a loss of more than 60%. The pomace from peels and cores is from 25 to 70% higher in grade than that from the peeled and cored apples. Pomace dried in commercial driers is lower in grade than that from the same apples dried in a laboratory drier, the differences being slight in some cases, although statistically significant.

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